DOCUMENT RESUME

ED 345 697 IR 015 505

AUTHOR Borsook, Terry K.; Higginbotham-Wheat, Nancy
TITLE A Psychology of Hypermedia: A Conceptual Framework for R&D.
PUB DATE 92
NOTE 21p.; Paper presented at the Annual Meeting of the Association for Educational Communications and Technology (Washington, DC, February 5-9, 1992).
PUB TYPE Information Analyses (070) -- Reports - Descriptive (141) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cognitive Processes; Cognitive Psychology; *Educational Psychology; Educational Technology; *Hypermedia; Instructional Effectiveness; Interactive Video; *Learning Theories; Multimedia Instruction; *Research and Development

ABSTRACT

This paper explores the insights that psychology can offer in shedding light on why hypermedia may work and thus in suggesting fruitful areas for future research. The philosophy underlying the paper is that research into the instructional efficacy of hypermedia should begin with a knowledge and appreciation of relevant psychological phenomena. Most discussions about hypertext tend to expound the virtues of hypertext and then go on to explain the coincidence of how this new technology happens to mirror the functioning of the brain. This paper takes the opposite approach, as it starts with an examination of theories and studies on how people learn, access, and use information and ideas, and only then moves on to consider the new technology that may mirror the way the brain works. Hypermedia has unique characteristics that point to relevant areas of learning research. An examination of the psychology and learning phenomena will inform the research and development of hypermedia. A brief explanation of the terms hypertext, hypermedia, interactive multimedia, interactive video, and multimedia is provided, followed by a discussion of various learning theories expounded in the literature of cognitive psychology. Cognitive flexibility theory, information processing theory, case based reasoning, generative learning, semantic networks, and dual coding theory are all discussed in reference to the new technology of hypermedia. (37 references) (Author/DB)

**********
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
**********

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☐ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

ED345697

# A PSYCHOLOGY OF HYPERMEDIA: A CONCEPTUAL FRAMEWORK FOR R & D

Terry K. Borsook
Corporate Learning Institute
Vanderbilt University
Nashville, Tennessee

Nancy Higginbotham-Wheat
Center of Excellence for Science & Mathematics Education
University of Tennessee at Martin
Martin, Tennessee

Paper presented at the Annual Meeting of the Association for Educational Communications and Technology, Washington, DC, February 5-9, 1992

IR015 505

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Nancy Higginbotham-Wheat

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."



BEST COPY AVAILABLE

**AUTHOR** Borsook, Terry K; Higginbotham-Wheat, Nancy

**TITLE** A Psychology of Hypermedia: A Conceptual Framework for R & D.

**PUB DATE** Feb 92

**NOTE** 18p; Paper presented at the Annual Meeting of the Association for Educational Communications and Technology. (Washington, DC, February 5-9, 1992).

**DESCRIPTORS** hypertext; hypermedia; cognitive flexibility theory; information processing theory; case-based reasoning; generative learning; semantic networks; dual coding theory

**ABSTRACT**

This paper explores the insights that psychology can offer in shedding light on why hypermedia may work and thus in suggesting fruitful areas for future research. The philosophy underlying the paper is that research into the instructional efficacy of hypermedia should begin with a knowledge and appreciation of relevant psychological phenomena. Most discussions about hypertext tend to expound the virtues of hypertext and then go on to explain the fortuitous coincidence of how this new technology happens to mirror the functioning of the brain—a solution looking for a problem to solve. The approach taken in this paper is the inverse of such an approach. It starts with an examination of theories and studies regarding how people learn, access, and use information and ideas, and only then moves to consider the new technology that may mirror the way our brains work.

Knowledge of new technologies offers us new opportunities for understanding how we learn as they provide new capabilities. In turn, knowledge of how we learn feeds back to guide the development of the new technologies, creating a wonderful cycle of progress. Hypermedia has unique characteristics that point us to relevant areas of learning research. An examination of the psychology and learning phenomena will, in turn, inform the research and development of hypermedia, which will then feed back to learning and psychology research, creating a most fecund feedback loop.

A brief explanation of the terms *hypertext*, *hypermedia*, *interactive multimedia*, *interactive video*, and *multimedia* is followed by a discussion of various learning theories expounded in the literature of cognitive psychology. Cognitive flexibility theory, information processing theory, case-based reasoning, generative learning, semantic networks, and dual coding theory are all discussed in reference to the new technology of hypermedia.

120580S

# A PSYCHOLOGY OF HYPERMEDIA: A CONCEPTUAL FRAMEWORK FOR R&D

## Introduction

> "More new information has been produced in the last 30 years than in the previous 5,000. About 1,000 books are published internationally every day and the total of all printed knowledge doubles every eight years."
>
> — Peter Large

> "We are like a thirsty person who has been condemned to use a thimble to drink from a fire hydrant."
>
> — Richard Saul Wurman

Think about a close friend. Perhaps she is an accountant. The concept of accountant is associated with many other concepts and ideas — taxes, green visors, a love of numbers, etc. Your friend has many attributes associated with her (e.g.,she is slender, she likes horror movies, she dresses elegantly, etc.) only one of which is that she is an accountant.

Now suppose a colleague complains about having to prepare this year's tax return. Your colleague's grousing triggers your thoughts about the concept of "accountant" which are, in turn, associated with your friend. Thinking about your friend now may remind you that you are scheduled to see a movie together on Friday, which may cause you to think of one of your favorite horror movies.

The mind seems to operate through associations. How else, then, could one go from a thought of accounting to thinking about horror stories? Thoughts often trigger other thoughts. Indeed, mental concentration is nothing more than the effort exerted to keep the mind from associating too much—to keep it focused on one thing at a time. Without the mind's penchant for associations, how could classical or operant conditioning be so powerful? Why would the creativity technique of *mindmapping* have become so popular? Why would hearing an old

song send many into an ecstasy of nostalgia? And why else would educators assert that the best way to make new material meaningful is to relate it to knowledge already in the brain? However the brain works, it is anything but linear.

Consider how one might classify a Dalmatian dog. As a dog? A pet? A spotted animal? A mammal? A fireman's companion? Clearly, the world resists classification into single, linear hierarchies; a Dalmatian can be associated with any number of other things. Now try to imagine the best way to classify a mouse. As a member of a group of animals called rodents? As a strange pet to have? As an undesirable house companion? Mice, like Dalmatians and everything else in the world, can fall under any number of classification schemes. Indeed, the Dalmatian and the mouse, both mammals, can also be classified as popular animated Disney characters.

The meaning we ascribe to a concept depends entirely on which classification scheme or set of associations is accessed. This access depends on the situation (i.e. context). Indeed, to the age-old question, "What is the meaning of life?", the answer is probably, "It depends." It depends on how we look at things, when we look at them, and even to what things we choose to attend. In other words, it depends upon how we construct our personal reality—how we perceive the world and even what we choose to include in our view of it.

If both the brain and the world around us consist of networks of highly interconnected ideas, concepts, processes and events, then linear educational media such as books and videotape are sorely inadequate to deal with this ever-expanding universe of information—highly interconnected, dynamic information. A new way of accessing and processing this information is needed.

This "new" idea was actually proposed almost fifty years ago. The man who proposed this new scheme knew much about the associative nature of both the brain and the world and also knew about how meek the tools of his time were for storing, accessing and using a steadily accumulating mass of information. The year was 1945 and the man was Vannevar Bush, science advisor to Franklin Roosevelt. Then, as now, scientific knowledge was accumulating at a rate far exceeding anyone's ability to make effective use of it. Bush believed that to enhance the acquisition of knowledge and to assist in viewing information in new and useful ways, one might wish to follow various trails, perhaps to wander off on a tangent and later return to the mainstream. For this endeavor, paper was

clearly inadequate. Bush's answer to the paper dilemma was the *memex*. In his own words,

> A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory. (pp. 106-107).

Bush later states,

> It affords an immediate step, however, to associative indexing, the basic idea of which is a provision whereby any item may be caused at will to select immediately and automatically another. This is the essential feature of the memex. The process of tying two items together is the important thing. (pp. 107).

Although the memex was never built, Bush set forth a vision that took almost half a century to materialize. The memex was the conceptual parent of what we now call *hypertext*.

**Hypertext/Hypermedia**

> Imagine a new accessibility and excitement that can unseat the video narcosis that now sits on our land like a fog. Imagine a new libertarian literature with alternative explanations so anyone can choose the pathway or approach that best suits him or her; with ideas accessible and interesting to everyone, so that a new richness and freedom can come to the human experience; imagine a rebirth of literacy. (Nelson, 1987; p. 1/4)

Despite its proclamation as a revolutionary information and learning tool, as a weapon believed to be a bastion of democracy and freedom, hypertext has always seemed like a solution in search of a problem—or perhaps a solution whose problems might outweigh its benefits. Yet it has an intuitive appeal that persists. It seems to be one of those things that we **know** is right because it just **feels** right. It is this intuitive appeal, recently proposed cognitive learning theories, and dizzying progress in technology that have synergistically fueled the hypertext mania.

Most discussions about hypertext tend to expound the virtues of hypertext and then go on to explain the fortuitous coincidence of how this new technology happens to mirror the functioning of the brain—a solution looking for a problem to solve. The approach taken in this paper is the inverse of such an approach. We will start with an examination of theories and studies regarding how people learn, access and use information and ideas, and only then move to consider the new technology that may mirror the way our brains work.

**Brief Glossary of Terms**

What exactly is hypermedia anyway? There is often some confusion regarding exactly what hypermedia is and what it is not. Five terms—interactive video, interactive multimedia, multimedia, hypertext and hypermedia—are often used interchangeably yet represent distinct ideas.

*Interactive video* (IV) combines the "interactive capability of the computer with the unique properties of video presentations" (Chen, 1990; p. 6). The typical interactive video arrangement includes a videodisc player connected to a personal computer, with the computer controlling the presentation of the video in response to interaction with the user. IV refers specifically to the **computer-videodisc player** combination. IV is a subset of interactive multimedia (see Evans, 1986).

*Interactive multimedia* refers to any computer-based configuration in which some combination of video, computer-generated graphics, sound, animation, and voice is used (see Ambron and Hooper, 1988, 1990; Stefanac and Weiman, 1990). These multimedia elements can either come from external sources such as videodisc players, VCRs or audio equipment, or they can be generated internally such as when video, sound or graphics are stored digitally on a hard disk or optical disk. What gives interactive multimedia its interactivity is the computer. Without the computer, the result is simply multimedia.

Of all the five terms, *multimedia* is the most difficult to define. The term has been used to refer to everything from slide shows to extravaganzas complete with multiple monitors, animation, video, sound and text. It would be easy to remember that multimedia stands for multiple media except that the term media can mean many things. "Media" can include slides, audiotapes, videotapes, videoconferencing, animation, films, music, voice, paper, or even someone shouting through a megaphone. Media can be instructional or not; it can be interactive or not; and it can be computer-based or not. While the focus of

interactive video, interactive multimedia, and multimedia is on the technology, the focus of *hypermedia* is on method—a method that so happens is most suited to the computer.

Understanding hypermedia depends on an understanding of its related term, *hypertext*. Quite different from the continuous flow of text inherent in traditional presentations of information, hypertext breaks up the flow into modules. "By modularizing information, users have the option of selecting the next module, which may include an elaboration or example of the present idea or an entirely new idea to be compared with the previous one." (Jonassen, 1989; p. 7).

Hypertext is often described as a computer-based method of nonsequential reading and writing—a technique with which chunks, or *nodes*, of information can be arranged and rearranged according to an individual's needs, previous knowledge, curiosities, etc. (Conklin, 1987; Jonassen, 1989; van Dam, 1988; Begoray, 1990; Hall and Papadopoulos, 1990). Hypertext not only *presents* information as a book does, it also *represents* information. As discussed earlier in this paper, meaning is derived from the arrangement of information. The implication here is two-fold: 1) Meaning is not static, but rather, dynamic—changing as the arrangement of nodes changes, and 2) Meaning resides in the relationships between the nodes, not in the nodes themselves. This insight is intriguing and has exciting implications for learning. According to Kearsley (1988), hypertext should improve learning by focusing attention on the relationships between ideas rather than on isolated facts. Associations provided by the links in hypertext should facilitate retrieval, concept formation, and comprehension.

*Hypermedia*, a term often used interchangeably with hypertext, is simply multimedia hypertext (Nielsen, 1990). That is, hyper*media* extends hyper*text* to include the full range of information forms: sound, graphics, animation, video, music, as well as text. As hypermedia is the more inclusive of the two terms, this paper will use the term hypermedia as a catch-all term referring to both text-based and multiple media-based systems.

The remainder of this paper will explore the insights that psychology can offer in shedding light on why hypermedia may work and thus in suggesting fruitful areas for future research. It is in this spirit that we should explore some of the psychological underpinnings of hypermedia.

## Some Psychological Underpinnings of Hypertext

Humans are perceived by cognitive theorists as being processors of information, acquiring knowledge and skills by way of interactive internal processes. These internal processes are orchestrated by a set of control processes which are personal, reflective of both innate abilities and individual experience.

Theories proposed by cognitive psychologists as well as strategies employed by cognitively oriented educators and instructional designers exhibit a basic cohesion in that humans are viewed as processing information by actively attending to stimuli, accessing existing knowledge to relate to new information, realigning the structure of that existing knowledge to accommodate new information, and encoding restructured knowledge into memory (Jonassen, 1985). The meaning that the individual ascribes to information is viewed as idiosyncratic, actively constructed from a base of existing knowledge (Winn, 1988). Our active participation in the construction of this new knowledge is viewed as a critical component for accessing and retrieving prior knowledge in the interpretation of new information (Weinstein, 1978). Thus, as we explore some of the ideas of what we know about how we learn and apply knowledge, it becomes obvious that activity as well as interactivity are integral components of both theory and its application in the technology of hypermedia.

### Cognitive Flexibility Theory

Many instructional systems fail, claim Rand Spiro and colleagues, because they do not take into consideration the *ill-structuredness* of many complex domains (Spiro and Jehng, 1990; Spiro, Feltovich, Jacobson, and Coulson, 1991). *Cognitive flexibility theory* is an attempt to explain how the brain makes sense of ill-structured domains (i.e. domains that are complex and in which there is little regularity from one case to another).

Essentially, the theory states that cognitive flexibility is needed in order to construct an ensemble of conceptual and case representations necessary to understand a particular problem-solving situation. The idea is that we cannot be

said to have a full understanding of a domain unless we have the opportunity to see different case representations.

According to Spiro et al., advanced knowledge requires an approach to learning that is quite different from that of introductory learning. The fundamental problem running throughout many learning efforts is "oversimplification." Oversimplification occurs in different forms. For example, *additivity bias* occurs when parts of complex entities are studied and it is assumed that these parts could be then re-integrated as a whole while retaining their original complex characteristics. Another example is *discreteness bias,* where continuous processes are divided up into discrete steps. Yet another form of oversimplification includes the *compartmentalization bias*, in which highly interrelated, interdependent concepts are considered in isolation from one another without consideration of how they interact.

Cognitive flexibility theory is an answer to the necessity of mastering complex subjects without falling prey to oversimplification in any or all of its forms. Basically, the theory posits that in order to learn complex material, the learner has to see that same material at different times, in different situations, for different purposes and from different conceptual perspectives (Spiro, Feltovich, Jacobson, and Coulson, 1991). Complete schemata are constructed to the extent that learners are exposed to multiple knowledge representations and multiple interconnectedness of the complex material to be learned.

Given the tenets of cognitive flexibility theory and what we know about the unique characteristics of hypermedia, it is easy to see the promising fit between the technology of hypermedia and the manner in which we allegedly best learn complex subject material. To make the potential fit of hypermedia to cognitive flexibility theory even stronger, recall that hypermedia is nothing more than a tool to link together nodes (chunks of information, or "conceptual elements") together in meaningful ways. This capability matches precisely the requirements of cognitive flexibility theory—the ability to see different aspects of a complex subject area from different perspectives in different contexts.

Hypermedia, therefore, has properties that are consistent with cognitive flexibility theory. For example, conceptual elements in the hypermedia environment can be re-arranged so that several conceptual elements can be viewed together. For another purpose, or in a different situation, conceptual elements could be arranged differently. Recall that it is the arrangement and relationships among nodes that give meaning to information. By freely

rearranging nodes according to specified features/properties depending on different needs, different contexts and different problems, learners have a powerful tool with which to learn and understand complex material in all its forms, in different situations, and in its entirety.

Even though hypermedia has been accused of being a solution in search of a problem, it is exciting to contemplate the idea that hypermedia may be just the opposite, a solution to the very tricky problem of how to effectively and efficiently teach complex, multifaceted subjects with many interconnected elements, such as medicine, literature, economics, etc. Given the almost made-to-measure fit of hypermedia to cognitive flexibility theory, it is important that we make it our top priority to take a closer look at *how* it fits and, perhaps more importantly, *why* it fits. Further research is required to clarify exactly how the brain deals with complex subject matter and how hypermedia systems can be shaped to facilitate optimal learning.

**Information Processing**

Information processing is proposed as an interactive system. An individual uses the physical senses to make sense out of the stimuli of the environment. This sensory recognition is interrelated with the individual's long-term memory, experiences, abilities, and expectations. Information is first received and recognized and is then either encoded and stored for later retrieval or is lost. The stages of information processing— recognition, short-term (working) memory storage, and long-term memory storage— are dependent on internal processes. What we remember, therefore, is a result of interactions within this system of active internal processes.

The system processes information by first recognizing patterns. If information is first recognized, it can then take on meaning. To extend our discussion of the concept of the Dalmatian dog, for example, we would first process the information presented by recognizing the pattern of the letters *DOG*. The combined alphabet letters *D*, *O*, and *G*, however, are not just recognized as individual letters in terms of how they are shaped; they represent a host of associations which have already been mentioned. Whether we are able to recognize this word and give it meaning each time we see the letters *DOG* depends on whether the information about *DOG* is stored in long-term memory

and can be retrieved into short-term memory (working memory) when called upon.

According to information processing theory, retention of information is attributed to basic processes—attention, selective perception, rehearsal, encoding, and retrieval—all of which occur throughout the three information processing stages. Current theorists put more emphasis on these processes and how they are affected rather than the stages in which they occur. To increase the probability that information is acquired, stored, and retrieved, we must somehow affect attention, selective perception, rehearsal, encoding, and retrieval. As processing occurs, information and skills are recoded to form stronger links to nodes and more pathways to stored information. According to theorists, information must be adequately encoded, stored, and retrieved to be remembered. Thus, ***any*** retention aid should encourage extra processing of information to increase links to stored skills. According to Tulving and Thomson (1973), the degree of accessibility of information stored in long-term memory is dependent on the strength of the cues encoded during acquisition. Strong cues, such as those cues which may be generated in hypermedia, are more likely to be present at recall.

**Case-Based Reasoning**

Case-based reasoning is an exciting educational paradigm in which learning depends on memory of specific experiences, or "cases" (Riesbeck and Schank, 1989). Medical and law schools have long utilized case-based instruction techniques in their curricula. Cases provide the means with which students can learn why, when, and how knowledge is applicable. In order to avoid the "inert knowledge problem" (see Whitehead, 1929; Bransford, Sherwood, Vye, & Rieser, 1986), learners must have the opportunity to organize new knowledge appropriately and know how and in what situations to apply the knowledge. The important point here is that instruction is more effective when anchored in meaningful problem-solving environments similar to those in which students will find themselves when solving actual real-world problems.

If the usefulness of information depends on an ability to recall it when appropriate, then it is important that cases be presented in such a way as to provide contextual cues to properly index information in memory. Hypermedia may facilitate this indexing by presenting information along with appropriate contextual cues. Ferguson et al. (1991) have created a hypermedia case-based

learning environment that helps organize information the same way in which the information will have to be organized when applied to some task.

**Generative Learning**

Cognitive principles suggest that learning is an active, constructive process in which learners generate meaning for information by accessing and applying existing knowledge. Generative learning theory incorporates these principles of cognitive psychology (Wittrock, 1974a, 1974b, 1979). The theory maintains that meaning for material is generated by activating and altering existing knowledge structures to interpret new information and encode it effectively for future retrieval and use. In Wittrock's (1974b) model, meaningful learning is a rational and transferable process:

> ... the generative model predicts that learning is a function of the abstract and distinctive, concrete associations which the learner generates between his prior experience, as it is stored in long-term memory, and the stimuli. Learning with understanding, which is defined by long term memory plus transfer to conceptually related problems, is a process of generating semantic and distinctive idiosyncratic associations between stimuli and stored information. (p. 89)

Comprehension, according to the generative model, requires the proactive transfer of existing knowledge to new material. Wittrock (1990) maintains, for example, that generative reading focuses on constructive or generative processes usually considered characteristic of good written composition. In other words, reading, like good writing, involves generative cognitive processes that create meaning by building relations among the parts of the text to be learned as well as between the text and what the learner knows, believes, and experiences. Learning activities which require the learner to relate new information to an existing knowledge structure depend on complex cognitive transformations and elaborations that are individual, personal, and contextual in nature. Generative learning activities, then, can be thought of as strategies which foster not only learning but learning-to-learn (Brown, Campione, & Day, 1981). In these learning activities, information is transformed and elaborated into a more individual form for the learner, thereby making the information more memorable as well as more comprehensible.

**Semantic Networks**

The nature of traditional media such as paper and video forces a linearity onto its content. Authors must arrange their work hierarchically so that one idea flows to the next and where ideas are subsumed under other ideas. As we have discussed earlier, however, the mind is anything but a linear thinking machine. Ideas are *not* arranged as on a scroll with one neatly leading to the next. In fact, it appears that the mind consists of endlessly intertwined webs of interrelated ideas, emotions and skills.

Quillian (1968) developed the idea of active structural networks (ASN) in an effort to capture and depict the ostensibly network-like nature of the brain. These networks consist of nodes (chunks of information) and labeled links (relationships) between nodes. Allegedly, everything someone might know could be encoded into the active structural networks of the brain. Furthermore, networks serve as structures within which new information is integrated with knowledge already possessed by the learner. The implication, then, is that learning involves the acquisition of new chunks of information and their connection to related chunks of information both new and old.

It is easy to see how active structural networks function by speaking in terms of schema theory. Schemata consist of interconnected sets of ideas which are further linked to other schemata. Meaningful learning takes place when new ideas are linked to other new ideas and when all are somehow assimilated into existing networks of schemata. While it might seem that the connections between nodes and between schemata are fixed except when new learning is taking place, the fact is quite the opposite. Relationships within and between schemata are defined in terms of context. The implication is that we remember and process ideas differently depending on the context.

It follows that it does not make sense to speak of an Absolute Truth about anything in our world, then, since the meaning of anything depends on how we perceive it in relation to other things. Recall our discussion of the Dalmatian dog. It is not adequately stating the Truth or the final word about Dalmatian dogs to say that they are members of a genus, the canines, within the class called mammals. We are no closer to absolute Truth if we add that they are members of a class of animals that are spotted. The Dalmatian dog is, in fact, a member of an extremely rich and diverse collection of interconnected ideas. It is a type of

carnivore which is a family of mammals, but it is also merely a dog. Dogs are associated with other concepts such as companionship, love, and with loud noises. They might also be associated with the thought of a good friend who owns four of them. The Dalmatian dog might also be connected to memories of childhood when the people next door had one. We could go on, *ad infinitum*, adding more and more to our Dalmatian dog schemata, but we could only approach the Truth, never arrive at it. As this demonstration suggests, meaning is *constructed* by each individual and is highly dependent on context. In learning, accessing and applying knowledge, only a small subset of the Truth is ever relevant. Indeed, this position is at the foundation of the increasingly popular educational movement, *constructivism*. Suchman (1987) argues that there is no ultimate reality. Instead, reality is relative and is the outcome of a constructive process. It is one's experience with an idea and the context of which the idea is a part that act together to construct a meaning of that idea (Brown, Collins, and Duguid, 1989).

All of this brings us back to the limitations of paper, video, and other linear systems. If learning involves the manipulation of networks of information and if the relationships binding these networks change depending on the context, the inadequacy of linear systems becomes clear. Within hypermedia, information can be rearranged, analyzed, shifted, and molded to suit the needs of each individual and the context in which the material is learned and/or applied. Hypermedia is a technology which can assist its users in constructing their schemata according to context and to individual needs and characteristics. The exact ways in which hypermedia can be made to facilitate schemata processing, however, requires a good deal more empirical research.

## Dual Coding Theory

The central theme underlying semantic network theory is that information is not simply filed away under a single heading, but rather is integrated in some way into a highly interconnected network of data and the relationships between those data. Dual coding theory (DCT) goes further in that it postulates that mental representations of ideas and events are stored in distinct verbal and nonverbal symbolic modes and that these representations retain the pattern of sensorimotor activation present during encoding (Clark and Paivio, 1991; Paivio, 1986).

One of the structural assumptions underlying DCT is that connections are formed both within verbal or nonverbal representations (associative connections) and between the two forms of representation (referential connections). For example, an associative connection would be one in which thinking about computers might remind you of related terms such as monitor, printer, and perhaps even frustration. A referential connection would be present if the word "mouse" conjured up memories of images of mice, the squeaking sounds they make and a sensation of anxiety. Thus, both *inter* and *intra*-associative structures exist between and within the two symbolic systems.

Mental representations are activated by related nodes in the network of associated nodes. Thoughts can activate associated nodes and then spread, resulting in a complex pattern of spreading activation among nodes and links in the network. Returning to our example of the dog,the sight of a Dalmatian dog might trigger the image of your neighbor who owns a Dalmatian. The image of your neighbor might, in turn, activate the thought of "dentist" as that is your neighbor's occupation, which might arouse a sense of uneasiness as you remember your last visit to the dentist.

This last example points out an important assumption of DCT specifically as well as active structural networks generally. As activation of nodes and associations spread out, they tend to weaken. It is easy to see how a thought of a Dalmatian could activate the thought of the dog's owner. It becomes increasingly ridiculous to speak of strong associations between verbal and nonverbal mental representations because, ultimately, everything is related! DCT, then, provides a plausible explanation of how the brain deals with information, in both verbal and nonverbal forms, which are more or less related to one another.

Another interesting aspect of DCT relevant to our discussion of hypermedia is that it emphasizes the role of past experience in the development of mental representations. Although two individuals may have the same experiences, their mental representations of these experiences will be different in significant ways, a function of their past experiences. Insights derived from DCT are consistent with the position taken by constructivists who maintain that there is no Truth out there, but rather that each individual's mental representation of reality is a constructed version of reality, and each person's construction is different from all others.

DCT makes it easy to see how beneficial hypermedia can be. First, one of the implications of DCT is that the more sensory modes in which mental

representations are stored, the more likely it is that they will be remembered. Hypermedia makes it easy to access related information in a wide variety of forms. A picture of a human heart can be accompanied by a motion video segment depicting blood flow through the ventricles, detailed drawings, textual explanations of anatomy and processes, and heartbeat sounds. All of this information could be immediately available at the click of an on-screen button. The quick and easy retrieval of related information in its different forms helps to build stronger relationships between these pieces of information than if one had to stop reading a textbook, retrieve a videotape, then an audiotape, then a carousel of slides, etc.

Another implication of DCT is that the mental representations constructed depend on context. If different people construct different representations of reality in order to conform to the context and their experiences, then it follows that any tool that helps people to personalize the information structure would be beneficial.

The idea of spreading activation suggests that it might be useful to assign values to links emanating from each node. The values assigned would represent the strength of the conceptual relationship between nodes. These values would indicate to users which of several links are the strongest, and would thus help users decide which links to traverse. Of course, there is no reason why users could not be provided with the means of assigning values to links themselves. The implications of active structural networks for hypermedia are many and exciting. Much research remains to be done in this area.

Dual coding theory has much to recommend hypermedia. It is a comprehensive theory of learning and suggests many implications for education. Its main idea is that all knowledge is constructed in the brain in many different forms and is different from person to person. All of this points up the need for learning and information acquisition tools that facilitate associative processing of information in a variety of forms, which are, in fact, integral to hypermedia.

**Bridging the Gap**

> What is hypertext? Hypertext is freedom! Freedom from the burdens of traditional computing applications. Freedom from fear of failure. Every hypertext user succeeds in getting somewhere and getting something. (Shneiderman and Kearsley, 1989; p. 2)
>
> All of this is manifest destiny. There is no point in arguing it; either you see it or you don't. Many readers will choke and fling down the book, only to have the thought gnaw gradually until they see its inevitability (Nelson, 1987; p. 0/12)

An attempt should be made to bridge the gap between what we know about how we learn and apply knowledge and a new technology that promises to augment the brain's functioning in a way never before possible. Hypertext and hypermedia have been trumpeted as revolutionary devices to help us deal with the geometrically increasing pool of information in the world. Among the many advantages hypermedia, claims include that it increases learner involvement and learner control, it focuses on relationships rather than isolated bits of data, it permits levels of explanations and it is easy to do annotations of all kinds.

All of these benefits are kudos to the technology of hypermedia itself. The technology permits information to be revealed as necessary (levels of explanation) in whatever order/arrangement is necessary (focus on relationships) and among other things, provides a nice method for uncovering side information or adding one's own side notes (annotation). The real intrigue of hypermedia, however, derives from its unique ensemble of characteristics which tantalizingly corroborate evidence regarding the way our brains work.

The idea of a machine based on associative indexing is not new (Bush, 1945), but the technology to materialize the vision is only now becoming available, with exciting new capabilities just over the horizon. While we explore the possibilities, however, we must not forget that the technology must *work for humans*, not the converse.

The philosophy underlying this paper is that research into the instructional efficacy of hypermedia should begin with a knowledge and appreciation of relevant psychological phenomena. This not to say that we should retreat, learn about how we learn and then return with an armload of instructional strategies to

be applied to the new technology. Ross and Morrison (1989) put it well,

> Aside from being difficult to accomplish, separating media from methods may not always be desirable in instructional technology research. Although media do not directly affect learning, they serve as influential moderating variables through their effects on learner attributions and their differential properties for conveying instructional strategies.(pp. 29-30).

Knowledge of new technologies offer us new opportunities for understanding how we learn as they provide new capabilities. In turn, knowledge of how we learn feeds back to guide the development of the new technologies, creating a wonderful cycle of progress. Hypermedia has unique characteristics that point us to relevant areas of learning research. Hopefully, an examination of the psychology and learning phenomena will, in turn, inform the research and development of hypermedia, which will then feed back to learning and psychology research, creating a most fecund feedback loop. Perhaps the conceptual father of hypermedia said it best when he wrote:

> There is a new profession of trail blazers, those who find delight in the task of establishing useful trails through the enormous mass of the common record. ...Thus science may implement the ways in which man produces, stores, and consults the record of the race. (Bush, 1945; p. 108)

We are in virgin territory. What is more, we are exploring this unknown territory in the dark. Every bit of knowledge we have about how we learn, process, and apply knowledge is like a spotlight beaming down on a small part of the foreign landscape. The more psychological knowledge we consider, the more spots will become illuminated, making more and more of the terrain visible and understood. But the spotlights are not erratic. They correspond to specific paths, much the same as streetlights light up not the whole city, but specific avenues throughout the city. Our paths lie within the psychology of learning. When aimed down on the unknown territory of the new technology, spotlights could illuminate the right paths that we must take to use the technology to enhance our ability to learn, process, and apply knowledge. This paper is an attempt to fire up as many of these spotlights as possible in order to light the way.

## References

Ambron, S., & Hooper, K. (Ed.). (1988). *Interactive multimedia: Visions of multimedia for developers, educators, & information providers*. Redmond, WA: Microsoft Press.

Ambron, S., & Hooper, K. (Ed.). (1990). *Learning with interactive multimedia: Developing and using multimedia tools in education*. Redmond, WA: Microsoft Press.

Begoray, J. A. (1990). An introduction to hypermedia issues, systems and applications areas. *Int. J. Man-Machine Studies*, **33**, 121-147.

Bransford, J. D.,Sherwood, R. S.,Vye, N. J., & Rieser, J. (1986). Teaching thinking and problem solving: Research foundations. *American Psychologist*, **41**, 1078-1089.

Brown, A. L., Campione, J. C., & Day, J. D. (1981). Learning to learn: On training students to learn from texts. *Educational Researcher*, *10*, 14-21.

Brown, J.S., Collins, A., and Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, **18**, 32-42.

Bush, V. (1945). As we may think. *Atlantic Monthly*, **Jul**, 101-108.

Chen, L.C. (1990). Interactive video technology in education: Past, present and future. *J. Educational Technology Systems*, **19**(1), 5-19.

Conklin, J. (1987). Hypertext: An introduction and survey. *IEEE Computer*, **Sept.**, 17-41.

Duffy, T.M., & Jonassen, D.H. (1991). Constructivism: New implications for instructional technology?, *Educational Technology*, **May**, 7-12.

Evans, A. D. (1986). Interactive video research: Past studies and directions for future research. *Int'l J. Intstructional Media*, **13**(4), 241-248.

Ferguson, W., Bareiss, R., Osgood, R., & Birnbaum, L. (1991). ASK Systems: An approach to story-based teaching. In Birnbaum, L. (Ed.) *Proceedings of the International Conference on the Learning Sciences*. Association for the advancement of computing in education. Charlottesville, VA.

Hall, P. A. V., & Papadopoulos (1990). Hypertext systems and applications. *Information and Software Technology*, **32**(7), 477-490.

Jonassen, D. H. (1985). Generative learning vs. mathemagenic control of text processing. In D. H. Jonassen (Ed.), *Technology of text: Principles for structuring, designing, and displaying text: Vol. 2* (pp. 9-45). Inglewood Cliffs, NJ: Educational Technology Publications.

Jonassen, D. H. (1986). Hypertext principles for text and courseware design. *Educational Psychologist*, **21**(4), 269-292.

Jonassen, D. H. (1989). *Hypertext / Hypermedia*. Englewood Cliffs, NJ: Educational Technology Publications.

Kearsley, G. (1988). Authoring considerations for hypertext. *Educational Technology*, **Nov.**, 21-24.

Nelson, T. H. (1987). *Literary Machines*. South Bend, IN: The Distributors.

Norman, D. A. (1973). *Cognitive organization and learning*. (Tech Report No. ED 083 543). Center for Human Information Processing. University of California, San Diego.

Norman, D. A. (1976). *Memory & Attention*. New York: John Wiley & Sons.

Norman, D. A., & Rumelhart, D. E. (1975). *Explorations in cognition*. San Francisco: W.H. Freeman Co.

Quillian, M. R. (1968). Semantic memory. In M. Minsky (Eds.), *Semantic information processing* (pp. 216-270). Cambridge, MA: MIT Press.

Riesbeck, C., & Schank, R. (Ed.). (1989). *Inside case-based reasoning*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Ross, S.M., & Morrison, G.R. (1989). In search of a happy medium in instructional technology research: Issues concerning external validity, media replications, and learner control. *ETR&D*, **37**(1), 19-33.

Shneiderman, B., & Kearsley, G. (1989). *Hypertext hands-on*! Reading, MA: Addison-Wesley Publishing.

Spiro, R. J., & Jehng, J. (1990). Cognitive flexibility and hypertext: Theory and technology for the nonlinear and multidimensional traversal of complex subject matter. In D. Nix & R. Spiro (Eds.), *Cognition, education, & multimedia: Exploring ideas in high technology*. Hillsdale, NJ: Lawrence Erlbaum.

Stefanac, S., & Weiman, L. (1990). Multimedia: Is it real? *Byte*, **Apr**, 116-123.

Suchman, L. A. (1987). *Plans and situated actions: The problem of human-machine communication*. Cambridge, UK: Cambridge University Press.

Tulving, E., & Tompson, D.M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, *80*. 352-373.

van Dam, A. (1988). Hypertext '87: Keynote Address. *Communications of the ACM*, **31**(7), 887-895.

Weinstein, C. E. (1978). Elaboration skills as a learning strategy. In H.F. O'Neil (Ed.), *Learning strategies*. New York: Academic Press.

Whitehead, A. N. (1929). *The aims of education*. New York: Macmillan.

Winn, W. D. (1988). Rethinking instructional design procedures in light of cognitive theory. Unpublished manuscript, University of Washington, Seattle.

Wittrock, M. C. (1974a). A generative model of mathematics learning. *Journal of Research in Mathematics Education, 5*, 181-197.

Wittrock, M.C. (1974b). Learning as a generative process. *Educational Psychologist, 11*, 87-95.

Wittrock, M.C. (1979). The cognitive movement in instruction. *Educational Researcher, 8* (2), 5-11.

Wittrock, M.C. (1990). Generative processes of comprehension. *Educational Psychologist*, 2
376.